

# Increasing Object-Level Reconstruction Quality in Single-Image 3D Scene Reconstruction

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## Abstract

## 1. Introduction

While humans can easily infer the 3D structure as well as the complete (panoptic) semantics of a scene from a single image, this task has been a longstanding challenge in the field of computer vision. The task fundamentally prerequisites learning a strong prior of the 3D world. Traditional methods have made significant strides, from generating geometrically coherent structures [6, 19] to learning different instance semantics [7, 12, 18]. More recent approaches directly learn the 3D panoptic semantics as a whole [5, 28], yet they fall short in capturing the intricate details and nuances at the object level. This paper introduces a novel approach to bridge this gap by integrating a specialized object-level model into the reconstruction process, thereby leveraging the specialized model’s object-priors.

## 2. Related Work

**2D panoptic segmentation** 2D panoptic segmentation merges semantic and instance segmentation, providing detailed pixel-level parsing of images, capturing both general categories (semantic segmentation) and individual object identities (instance segmentation) [10]. Since the original task formulation by Kirillov et al. [10], a number of works have been proposed to solve the task [1–3, 11, 13–15, 17, 21, 22, 25–27], while more recent approaches [9] try to unify image segmentation in its entirety.

**Single-view 3D reconstruction** The work by Snavely et al. [20] was the first notable attempt at reconstructing 3D scenes from unordered photo collections. Since then, the field of image-based 3D reconstruction has seen a number of advancements, culminating in the task of single-view 3D reconstruction [4, 6, 8, 16, 18, 19, 23].

**Shape priors** Wu et al. [24] note that the task of single-view 3D reconstruction is non-deterministic, as there are many 3D shapes that can explain a given single-view input, and propose to use shape priors to shape the solution space such that the reconstructed shapes are realistic, but not necessarily the ground truth.

## 3D scene understanding and panoptic reconstruction

## DATASET

## 3. Method

## 4. Conclusion

## References

- [1] Ting Chen, Lala Li, Saurabh Saxena, Geoffrey Hinton, and David J. Fleet. A generalist framework for panoptic segmentation of images and videos. In *Proceedings of the IEEE/CVF International Conference on Computer Vision (ICCV)*, pages 909–919, 2023. 1
- [2] Bowen Cheng, Maxwell D Collins, Yukun Zhu, Ting Liu, Thomas S Huang, Hartwig Adam, and Liang-Chieh Chen. Panoptic-deeplab: A simple, strong, and fast baseline for bottom-up panoptic segmentation. In *Proceedings of the IEEE/CVF conference on computer vision and pattern recognition*, pages 12475–12485, 2020.
- [3] Bowen Cheng, Ishan Misra, Alexander G. Schwing, Alexander Kirillov, and Rohit Girdhar. Masked-attention mask transformer for universal image segmentation. In *Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition (CVPR)*, pages 1290–1299, 2022. 1
- [4] Christopher B Choy, Danfei Xu, JunYoung Gwak, Kevin Chen, and Silvio Savarese. 3d-r2n2: A unified approach for single and multi-view 3d object reconstruction. In *Computer Vision—ECCV 2016: 14th European Conference, Amsterdam, The Netherlands, October 11–14, 2016, Proceedings, Part VIII 14*, pages 628–644. Springer, 2016. 1
- [5] Manuel Dahnert, Ji Hou, Matthias Nießner, and Angela Dai. Panoptic 3d scene reconstruction from a single rgb image.

*Advances in Neural Information Processing Systems*, 34:8282–8293, 2021. 1

- [6] Maximilian Denninger and Rudolph Triebel. 3d scene reconstruction from a single viewport. In *European Conference on Computer Vision*, pages 51–67. Springer, 2020. 1
- [7] Georgia Gkioxari, Jitendra Malik, and Justin Johnson. Mesh r-cnn. In *Proceedings of the IEEE/CVF international conference on computer vision*, pages 9785–9795, 2019. 1
- [8] Siyuan Huang, Yixin Chen, Tao Yuan, Siyuan Qi, Yixin Zhu, and Song-Chun Zhu. Perspectivenet: 3d object detection from a single rgb image via perspective points. *Advances in neural information processing systems*, 32, 2019. 1
- [9] Jitesh Jain, Jiachen Li, Mang Tik Chiu, Ali Hassani, Nikita Orlov, and Humphrey Shi. Oneformer: One transformer to rule universal image segmentation. In *Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition (CVPR)*, pages 2989–2998, 2023. 1
- [10] Alexander Kirillov, Kaiming He, Ross Girshick, Carsten Rother, and Piotr Dollár. Panoptic segmentation. In *Proceedings of the IEEE/CVF conference on computer vision and pattern recognition*, pages 9404–9413, 2019. 1
- [11] Abhijit Kundu, Kyle Genova, Xiaoqi Yin, Alireza Fathi, Caroline Pantofaru, Leonidas J. Guibas, Andrea Tagliasacchi, Frank Dellaert, and Thomas Funkhouser. Panoptic neural fields: A semantic object-aware neural scene representation. In *Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition (CVPR)*, pages 12871–12881, 2022. 1
- [12] Weicheng Kuo, Anelia Angelova, Tsung-Yi Lin, and Angela Dai. Mask2cad: 3d shape prediction by learning to segment and retrieve. In *Computer Vision—ECCV 2020: 16th European Conference, Glasgow, UK, August 23–28, 2020, Proceedings, Part III 16*, pages 260–277. Springer, 2020. 1
- [13] Feng Li, Hao Zhang, Huaizhe Xu, Shilong Liu, Lei Zhang, Lionel M Ni, and Heung-Yeung Shum. Mask dino: Towards a unified transformer-based framework for object detection and segmentation. In *Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition*, pages 3041–3050, 2023. 1
- [14] Yanwei Li, Hengshuang Zhao, Xiaojuan Qi, Liwei Wang, Zeming Li, Jian Sun, and Jiaya Jia. Fully convolutional networks for panoptic segmentation. In *Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition (CVPR)*, pages 214–223, 2021.
- [15] Zhiqi Li, Wenhai Wang, Enze Xie, Zhiding Yu, Anima Anandkumar, Jose M. Alvarez, Ping Luo, and Tong Lu. Panoptic segformer: Delving deeper into panoptic segmentation with transformers. In *Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition (CVPR)*, pages 1280–1289, 2022. 1
- [16] Lars Mescheder, Michael Oechsle, Michael Niemeyer, Sebastian Nowozin, and Andreas Geiger. Occupancy networks: Learning 3d reconstruction in function space. In *Proceedings of the IEEE/CVF conference on computer vision and pattern recognition*, pages 4460–4470, 2019. 1
- [17] Rohit Mohan and Abhinav Valada. Efficientps: Efficient panoptic segmentation. *International Journal of Computer Vision*, 129(5):1551–1579, 2021. 1
- [18] Yinyu Nie, Xiaoguang Han, Shihui Guo, Yujian Zheng, Jian Chang, and Jian Jun Zhang. Total3dunderstanding: Joint layout, object pose and mesh reconstruction for indoor scenes from a single image. In *Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition*, pages 55–64, 2020. 1
- [19] Daeyun Shin, Zhile Ren, Erik B Sudderth, and Charles C Fowlkes. 3d scene reconstruction with multi-layer depth and epipolar transformers. In *Proceedings of the IEEE/CVF international conference on computer vision*, pages 2172–2182, 2019. 1
- [20] Noah Snavely, Steven M Seitz, and Richard Szeliski. Photo tourism: exploring photo collections in 3d. In *ACM siggraph 2006 papers*, pages 835–846. 2006. 1
- [21] Huiyu Wang, Yukun Zhu, Bradley Green, Hartwig Adam, Alan Yuille, and Liang-Chieh Chen. Axial-deeplab: Stand-alone axial-attention for panoptic segmentation. In *European conference on computer vision*, pages 108–126. Springer, 2020. 1
- [22] Huiyu Wang, Yukun Zhu, Hartwig Adam, Alan Yuille, and Liang-Chieh Chen. Max-deeplab: End-to-end panoptic segmentation with mask transformers. In *Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition (CVPR)*, pages 5463–5474, 2021. 1
- [23] Nanyang Wang, Yinda Zhang, Zhuwen Li, Yanwei Fu, Wei Liu, and Yu-Gang Jiang. Pixel2mesh: Generating 3d mesh models from single rgb images. In *Proceedings of the European conference on computer vision (ECCV)*, pages 52–67, 2018. 1
- [24] Jiajun Wu, Chengkai Zhang, Xiuming Zhang, Zhoutong Zhang, William T Freeman, and Joshua B Tenenbaum. Learning shape priors for single-view 3d completion and reconstruction. In *Proceedings of the European Conference on Computer Vision (ECCV)*, pages 646–662, 2018. 1
- [25] Jiarui Xu, Sifei Liu, Arash Vahdat, Wonmin Byeon, Xiaolong Wang, and Shalini De Mello. Open-vocabulary panoptic segmentation with text-to-image diffusion models. In *Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition (CVPR)*, pages 2955–2966, 2023. 1
- [26] Qihang Yu, Huiyu Wang, Dahun Kim, Siyuan Qiao, Maxwell Collins, Yukun Zhu, Hartwig Adam, Alan Yuille, and Liang-Chieh Chen. Cmt-deeplab: Clustering mask transformers for panoptic segmentation. In *Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition (CVPR)*, pages 2560–2570, 2022.
- [27] Qihang Yu, Ju He, Xueqing Deng, Xiaohui Shen, and Liang-Chieh Chen. Convolutions die hard: Open-vocabulary segmentation with single frozen convolutional clip. *arXiv preprint arXiv:2308.02487*, 2023. 1
- [28] Xiang Zhang, Zeyuan Chen, Fangyin Wei, and Zhuowen Tu. Uni-3d: A universal model for panoptic 3d scene reconstruction. In *Proceedings of the IEEE/CVF International Conference on Computer Vision*, pages 9256–9266, 2023. 1